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RESEARCH MEMORANDUM

for the

Air Materiel Command, U.S. Air Force

DITCHING TESTS OF A $\frac{1}{20}$-SCALE MODEL

OF THE NORTHROP B-35 AIRPLANE

By

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SUMMARY

Tests of a $\frac{1}{20}$-scale dynamically similar model of the Northrop B-35 airplane were made to study its ditching characteristics. The model was ditched in calm water at the Langley tank no. 2 monorail.

Various landing attitudes, speeds, and conditions of damage were simulated during the investigation. The ditching characteristics were determined by visual observation and from motion-picture records and time-history acceleration records. Both longitudinal and lateral accelerations were measured. Results are given in tabular form and time-history acceleration curves and sequence photographs are presented.

Conclusions based on the model investigation are as follows:

1. The best ditching of the B-35 airplane probably can be made by contacting the water in a near normal landing attitude of about 9° with the landing flaps full down so as to have a low horizontal speed.

2. The airplane usually will turn or yaw but the motion will not be violent. The maximum lateral acceleration will be about 2g.

3. If the airplane does not turn or yaw immediately after landing, it probably will trim up and then make a smooth run or porpoise slightly. The maximum longitudinal decelerations that will be encountered are about 6g or 7g.

4. Although the decelerations are not indicated to be especially large, the construction of the airplane is such that extensive damage is to be expected, and it probably will be difficult to find ditching stations where crew members can adequately brace themselves and be reasonably sure of avoiding a large inrush of water.

INTRODUCTION

The ditching characteristics of several landplanes have been inves-
tigated in Langley tank no. 2. The present investigation is an extension
of these tests and was requested by the Air Materiel Command, U.S. Air
Force. Model tests were made to determine the probable ditching charac-
teristics of the B-35 and to determine the best way to ditch that air-
plane. A knowledge of what would happen to a landplane in a ditching is
of great importance to its crew, passengers, and operating agency if
there is any possibility of flight over large expanses of water. Various
landing attitudes, speeds, and conditions of damage were simulated in the
tests and the model was ditched in calm water at the Langley tank no. 2
monorail.

Data on the full-scale airplane were obtained from Northrop
Aircraft, Inc. A three-view drawing of the B-35 is shown in figure 1.

APPARATUS AND PROCEDURE

Description of Model

A $\frac{1}{20}$-scale dynamically similar model of the Northrop B-35 airplane
having a wing span of 8.6 feet was used in the tests. Photographs of the
model are given in figure 2. The model was constructed of balsa ribs and
planking with pieces of spruce at points of concentrated stress and with
hardwood spars. The flaps, elevons, and rudders were constructed of pine
ribs and spars covered with silk. Metal parts used for quadrants, hinges,
and other fittings were made of brass or duralumin.

In order to simulate structural failure of various parts of the model
such as bomb-bay doors or wheel doors, the parts were completely removed.
Of course, damage to the full-scale airplane would result in dented,
torn, and dangling parts instead of clean cuts, as on the model; but from
previous experience with full-scale and model ditchings, it can be expected
that the length of runs and general behavior of the model (turning,
skipping, porpoising) will be about the same as that of the full-scale
airplane.

The landing flaps were installed on the model in such a manner that
they could be held in the down position by a calibrated string that would
fail when a load equal to the scale strength of the flap was applied.
(See fig. 3.) Failure of a flap was simulated by the string breaking
and the flap rotating on its hinges to the up position. The trim flaps,
elevons, and rudders were also hinged and could be adjusted to balance
the model aerodynamically.

Test Methods and Equipment

When the model had been balanced statically with ballast distributed so that the rolling, pitching, and yawing moments of inertia corresponded to those of the airplane, it was attached (at the desired landing attitude) to the launching carriage and then catapulted into the air. The control surfaces were set so that the model would glide onto the water at approximately the desired attitude. The initial settings of the control surfaces were made using data obtained from wind-tunnel tests reported in reference 1, and slight adjustments were made on subsequent launchings if the glide and attitude on landing were not satisfactory.

The results of the tests were obtained by visual observation and from motion-picture records and the time-history acceleration records. Both longitudinal and lateral accelerations were measured. Accelerations were measured with a single-component accelerometer located in the model near the pilot's cockpit. In order to get the two components of acceleration, repeat tests were made with the accelerometer rotated.

Test Conditions

All values given herein refer to the full-scale airplane.

Gross weight.- A gross weight of 150,000 pounds was simulated in the tests.

Location of the center of gravity.- The center of gravity was located at 24.8 percent of the mean aerodynamic chord and 10.0 inches above the root-chord line (horizontal reference line).

Landing attitude.- Ditchings were made at three landing attitudes: 4°, 9°, and 14°. Attitude is the inclination of the root-chord line to the smooth water surface. The 4° attitude is near the three-wheel static attitude, the 14° attitude is near the stall angle, and the 9° attitude is an intermediate angle that is approximately the normal landing attitude.

Landing gear.- The tests simulated ditchings with the landing gear retracted.

Flaps.- Full-down landing flaps were used throughout the tests in order to obtain as low a horizontal landing speed as possible at the various attitudes. A flaps-up condition was not tested because it was believed that excessive damage would occur in a flaps-up landing because of the inherently high landing speed. Scale-strength landing flaps were used in the tests. The scale strength was based on an ultimate loading normal to the undersurface of the flap of 140 pounds per square foot. The trim flaps and elevons were set as necessary to obtain the various landing attitudes but were never in the down position; so they were not made scale strength.

Landing speeds.- The landing speeds used in the tests are listed in
table I. They are speeds at which the model was just air-borne and are
approximately the speeds computed using lift curves presented in refer-
ence 1.

Conditions of simulated damage.- An estimate of the load required to
cause failure of some of the parts of the bottom of the B-35 (based on
data obtained from Northrop Aircraft, Inc.) is as follows:

Bomb-bay doors, pounds per square foot 115
Two lower entrance hatches, pounds per square foot 2160
Lower ball sighting station and external
    parts of lower turrets. . . . . Negligible
Interior of crew nacelle, pounds per square foot 2160
Rear spar and trailing edge of wing in region
    aft of bomb bays, pounds per square foot . . . . 400 to 720

These loads indicate that the crew nacelle is moderately strong but that
the remainder of the airplane is relatively weak.

The model was tested at the following conditions of simulated damage:

(a) No damage (See fig. 2.)

(b) Simulated failure of bomb-bay doors, lower turrets, lower ball
sighting station, and aft part of main-wheel doors (fig. 4)

(c) Simulated failure of bomb-bay doors, lower turrets, lower ball
sighting station, aft part of main-wheel doors, engine doors, and
bombardier's window (fig. 5)

In addition to the damage mentioned above as test conditions, the
model was frequently damaged during the tests by contact with the water;
the landing flaps, elevons, or trim flaps were broken off or the planking
on the underside of the wing near the tips was torn away (fig. 6).

It is possible that in a full-scale ditching the airplane would
sustain more extensive damage than was feasible to simulate on the model.
For example, the trailing edge of the wing in the region aft of the
bomb bays might be torn off in a ditching, but if this part was removed
from the model, there would be appreciable difficulty in providing enough
structure to support the planking on the wing forward of this section,
the landing flaps, or the outer wing section; these parts are necessary
if the model is to be ditched by gliding onto the water. But, even
though an airplane may be damaged more extensively than the model was, in
all probability its behavior will be about the same as that of the model
because, when the model was damaged during the tests by contact with the
water, the behavior was not noticeably affected.

RESULTS AND DISCUSSION

A summary of the results of the tests is presented in table I. The symbols used in the table are defined as follows:

b   ran deeply - the model traveled through the water submerged somewhat
     deeper than was usual in the other test runs

h   ran smoothly - the model traveled through the water with no apparent
     oscillation about any axis, settling in the water as the forward
     velocity decreased

p   porpoised - the model traveled through the water with an undulating
     motion about the lateral axis with some part of the model always
     in contact with the water

t   turned or yawed - the model either turned on a fairly large radius
     or yawed

u   trimmed up - the attitude of the model increased immediately after
     contact with the water

Photographs showing the characteristic behavior of the model are given in figure 7. Typical time histories of longitudinal and lateral accelerations are given in figures 8 and 9.

General

The model tests showed that the most pronounced ditching characteristic of the B-35 was its tendency to turn or yaw. Turning occurred much more frequently than did yawing. A turn or yaw developed if either wing tip was only slightly low on landing or dropped during the run. A turn was usually gradual and might occur either immediately after landing or near the end of the run. A yaw usually occurred near the beginning of the run; the model skidded along in the yawed position and near the end of the run usually turned off in the direction of yaw. Neither a turn nor a yaw seemed to be very dangerous, but personnel that ditch in a B-35 should be braced to withstand both longitudinal and lateral accelerations. The maximum longitudinal decelerations obtained in the tests were about 6g or 7g. (See table I and fig. 8.) The maximum lateral accelerations were about 2g (fig. 9). The positive values of lateral acceleration are in the direction toward which the model turned or yawed. The duration of the accelerations is shown in figures 8 and 9 but is not very great for the higher values of acceleration.

There always seemed to be a rather strong suction under the wing toward the trailing edge. This down force probably caused the model to trim up when landed at the 9° and 4° attitudes and caused the planking on the wing near the tips to be torn away. In tests of the undamaged model, there was a tendency for the bomb-bay doors to be forced out.

Effect of Damage

The amount of simulated damage did not greatly affect the behavior of the model. The runs were somewhat shortened and the model ran deeper in the water as the amount of damage was increased but the type of motion made by the model did not change appreciably. The damage that occasionally occurred to the model due to contact with the water had practically no effect on its behavior. Although the decelerations are not indicated to be especially large, the construction of the airplane is such that extensive damage can be expected and it probably will be difficult to find ditching stations where crew members can adequately brace themselves and be reasonably sure of avoiding a large inrush of water.

Effect of Attitude

The landing attitude had no effect on the tendency of the model to yaw. The following effects of attitude are for tests in which straight runs were made or in which a turn did not occur until near the end of the run. At the 14° attitude, the model made smooth runs, running somewhat deeper in the water as the amount of damage was increased. At the 9° attitude, the model trimmed up soon after landing and then either porpoised slightly or made a smooth run, depending on the damage. At the 4° attitude, the model trimmed up soon after landing and then porpoised. The shortest runs and highest decelerations were made at 14°. The longest runs and lowest decelerations were made at 4°. (See table I.)

There is not a great difference in ditching behavior at the various attitudes; so on the basis of the high speeds associated with a 4° landing and the high decelerations and short runs obtained at 14°, a 9° landing attitude is recommended.

Effect of Flaps

Full-down scale-strength landing flaps were used throughout the tests. There seemed to be no adverse effects on the ditching character- istics that could be attributed to the flaps although no tests were made with flaps up. The flaps are relatively weak and always failed immediately on contact with the water. Full-down landing flaps are recommended in a ditching in order to obtain a low horizontal speed.

CONCLUSIONS

Conclusions based on model tests of the Northrop B-35 airplane are as follows:

1. The best ditching of the B-35 airplane probably can be made by contacting the water in a near-normal landing attitude of about 9° with the landing flaps full-down so as to have a low horizontal landing speed.

2. The airplane usually will turn or yaw, but the motion will not be violent. The maximum lateral acceleration will be about 2g.

3. If the airplane does not turn or yaw immediately after landing, it probably will trim up and then make a smooth run or porpoise slightly. The maximum longitudinal decelerations that will be encountered are about 6g or 7g.

4. Although the decelerations are not indicated to be especially large, the construction of the airplane is such that extensive damage is to be expected and it probably will be difficult to find ditching stations where crew members can adequately brace themselves and be reasonably sure of avoiding a large inrush of water.

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JCR

                                REFERENCES

1. Teplitz, Jerome, Kayten, Gerald G., and Cancro, Patrick A.: Tests of a 1/7-Scale Semispan Model of the XB-35 Airplane in the Langley 19-Foot Pressure Tunnel. NACA MR No. L7L27, Army Air Forces, 1946.

TABLE I.- SUMMARY OF RESULTS OF DITCHING TESTS IN CALM WATER

OF A $\frac{1}{20}$-SCALE MODEL OF THE NORTHROP B-35 AIRPLANE

[Gross weight 150,000 pounds; landing flaps full-down;
all values full scale]

Landing attitude, deg	14			9			4		
Landing speed, mph	113			128			143		
Damage condition	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model (a)	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model (a)	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model (a)
No damage					400 400	ht pt			
Simulated failure of bomb-bay doors, lower turrets, lower ball sighting station, aft part of main-wheel doors		280 280	ht bt		300 300	ht uht		480	upt
Simulated failure of bomb-bay doors, lower turrets, lower ball sighting station, aft part of main-wheel doors, engine doors, bombardier's window	6 7	240 240	b bt	5 6	300 300	up upt	5	500	upt

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aMotions of the model are denoted by the following symbols:
  b - ran deeply
  h - ran smoothly
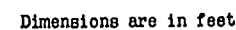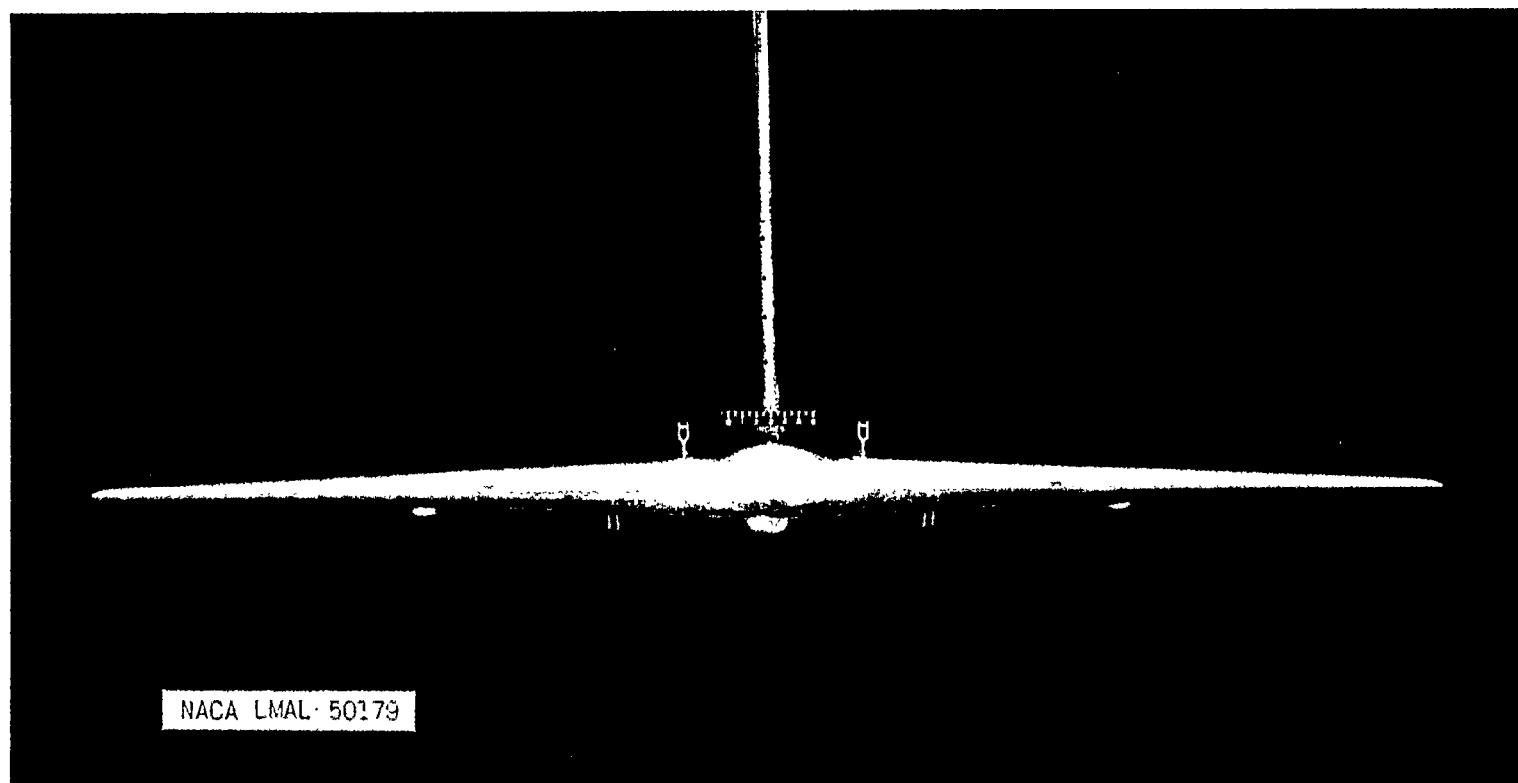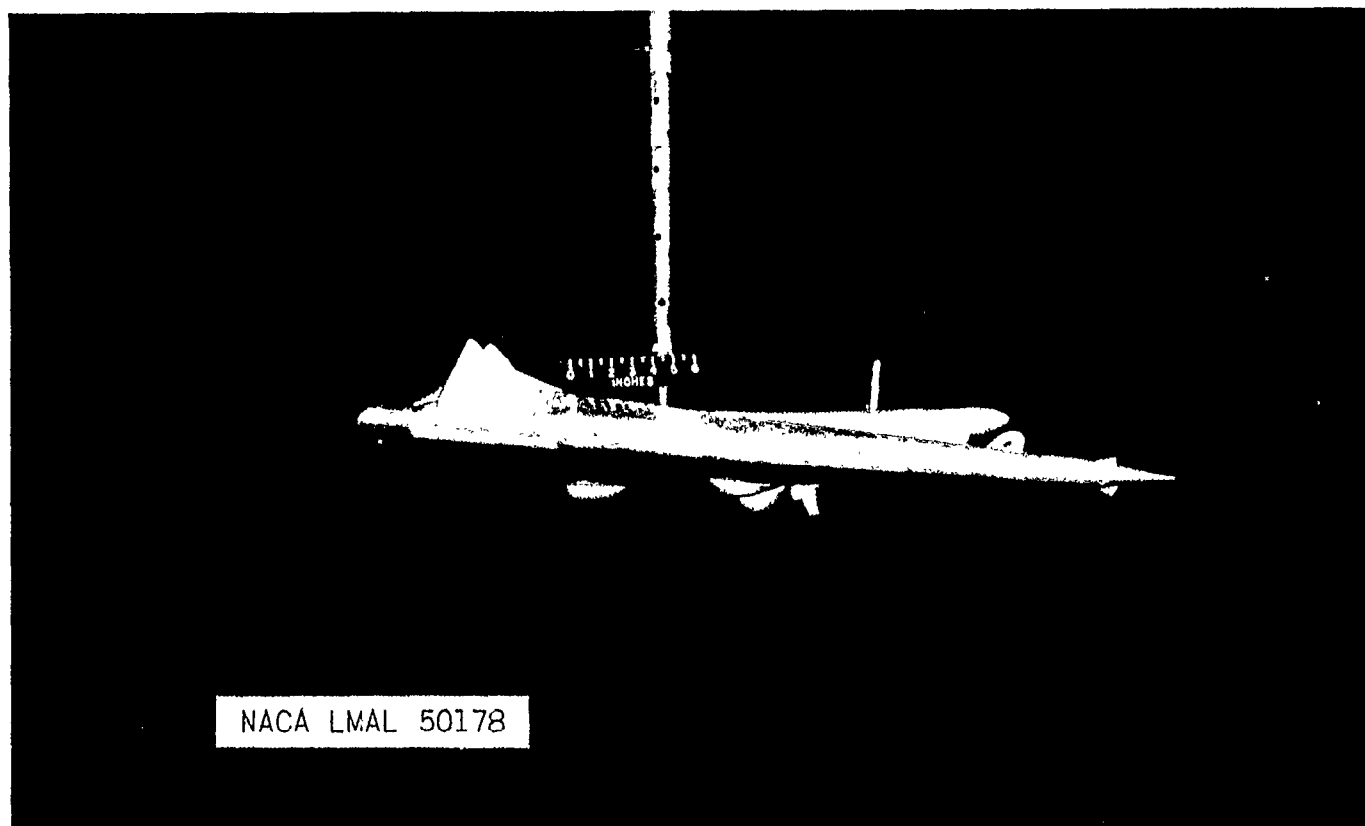 p - porpoised
  t - turned or yawed
  u - trimmed up

Figure 1.- Three-view drawing of the Northrop B-35 airplane.

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(a) Front view.

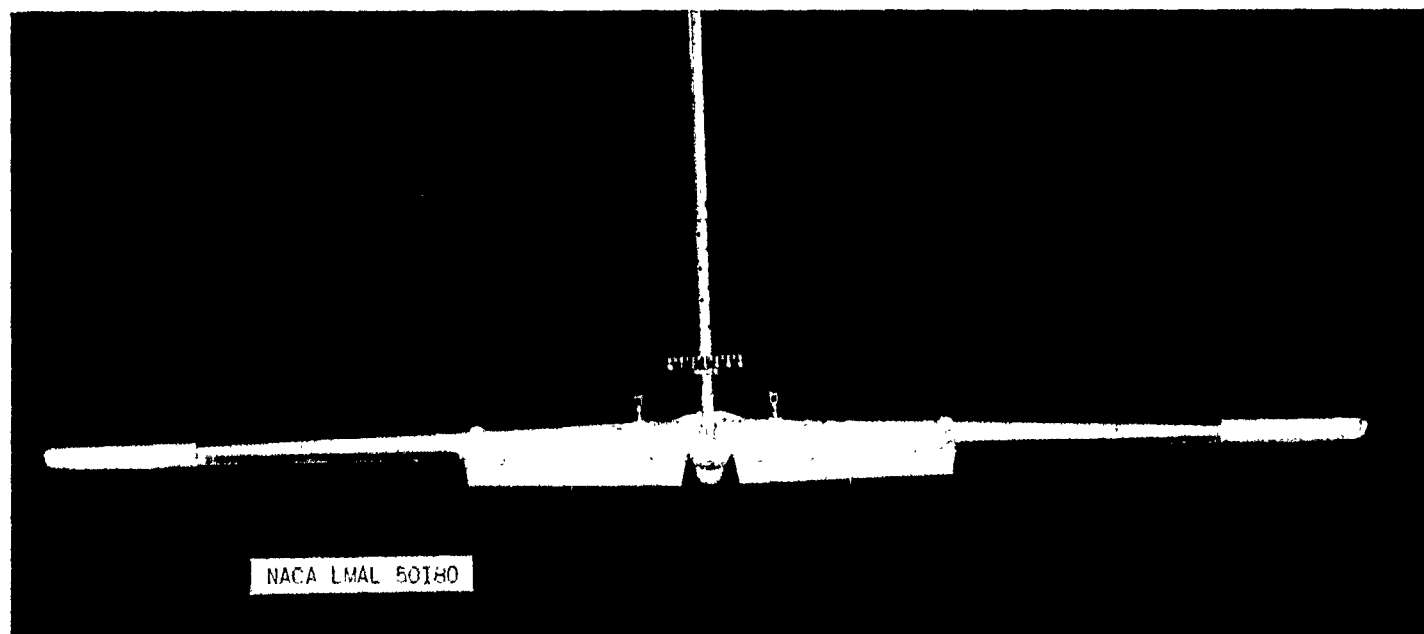Figure 2.- Northrop B-35 airplane, $\frac{1}{20}$-scale dynamic model.

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(b) Side view.

Figure 2.- Continued.
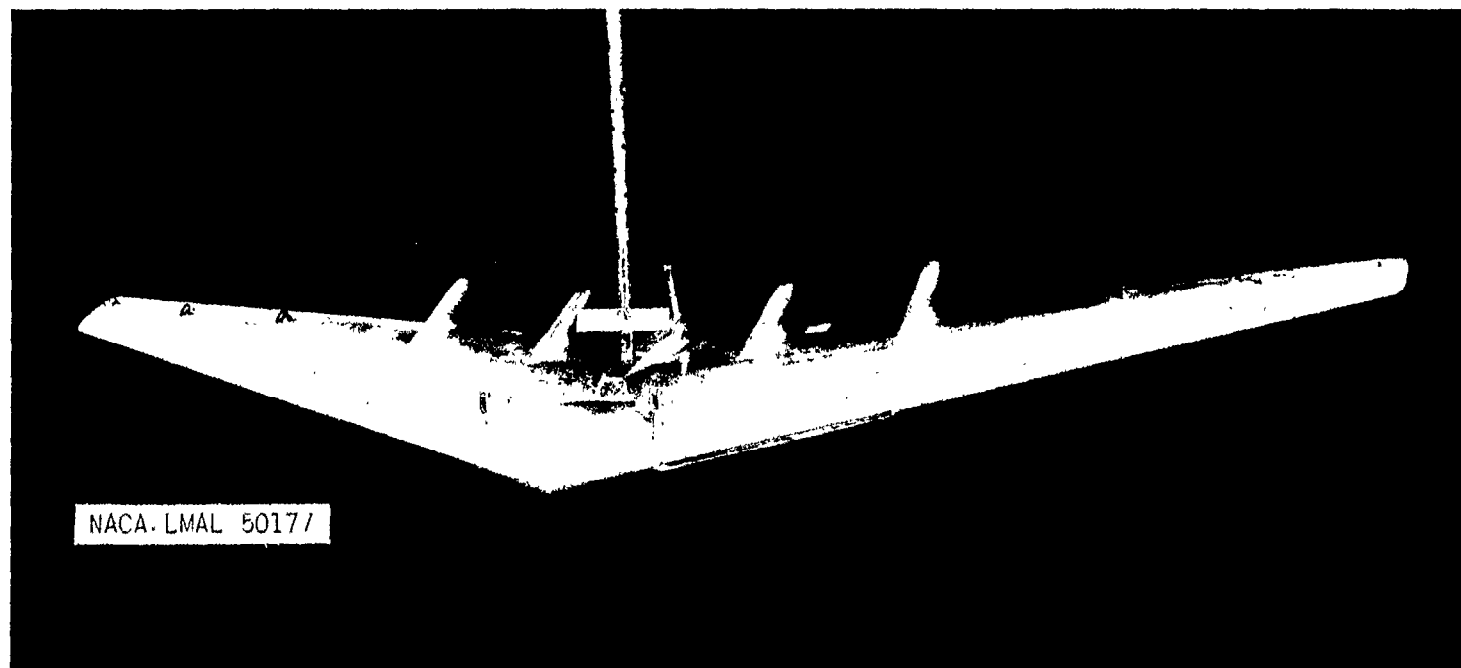
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(c) Rear view.

Figure 2.- Continued.

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(d)   Three-quarter top view.

Figure 2.-   Continued.

NACA LMAL 50174
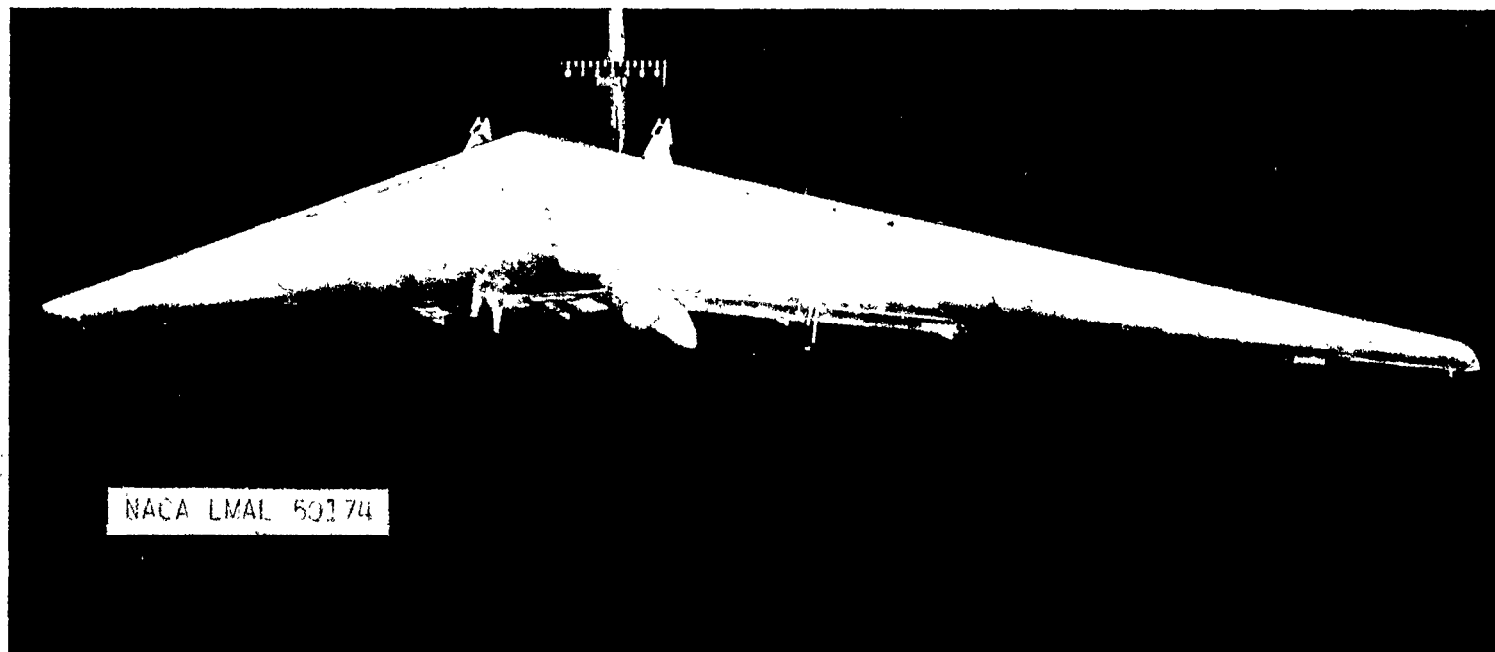
(e)   Three-quarter bottom view.

Figure 2.-   Concluded.

Wing

Hinge

String
(known strength)

Flap

String to insure
correct flap angle

Note: The fitting is
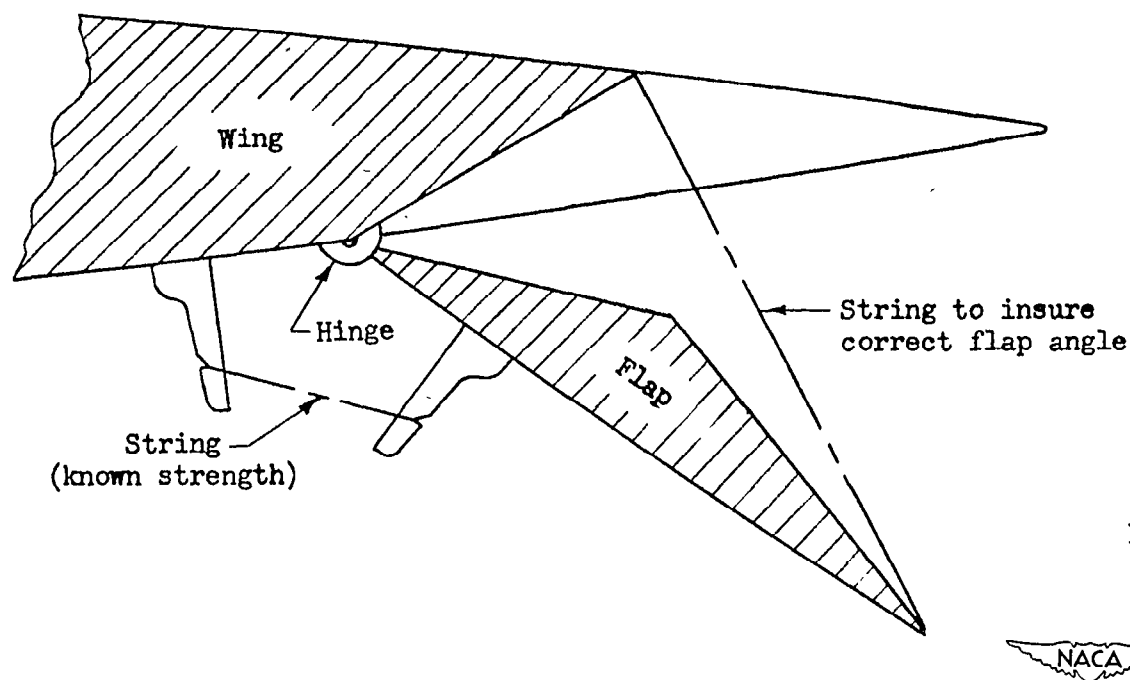located at mid-span
of each flap.

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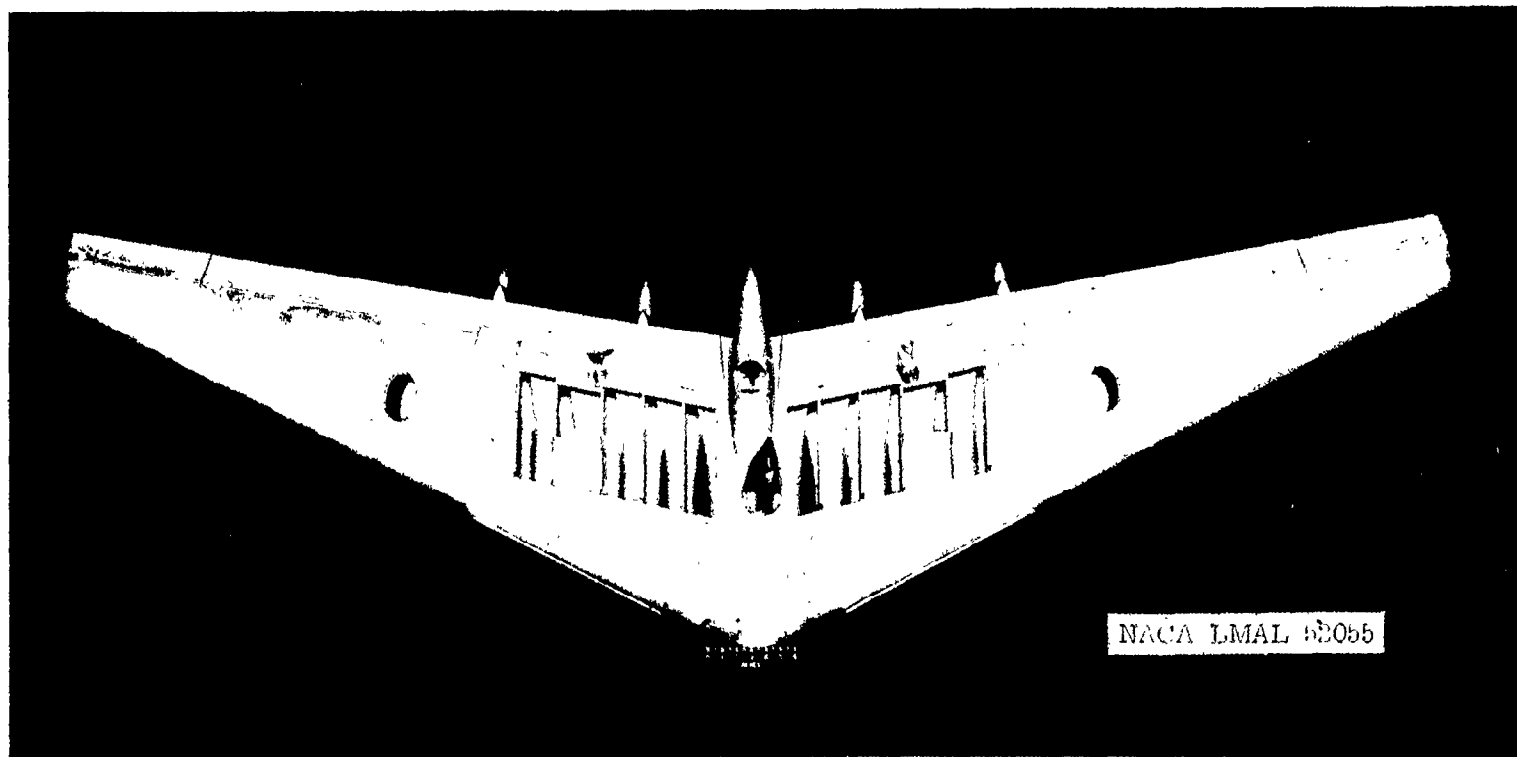Figure 3.- Method used to obtain scale-strength landing flaps.

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Figure 4.- Bottom view of model with bomb-bay doors, lower turrets, lower ball sighting station, and aft part of main-wheel doors removed.
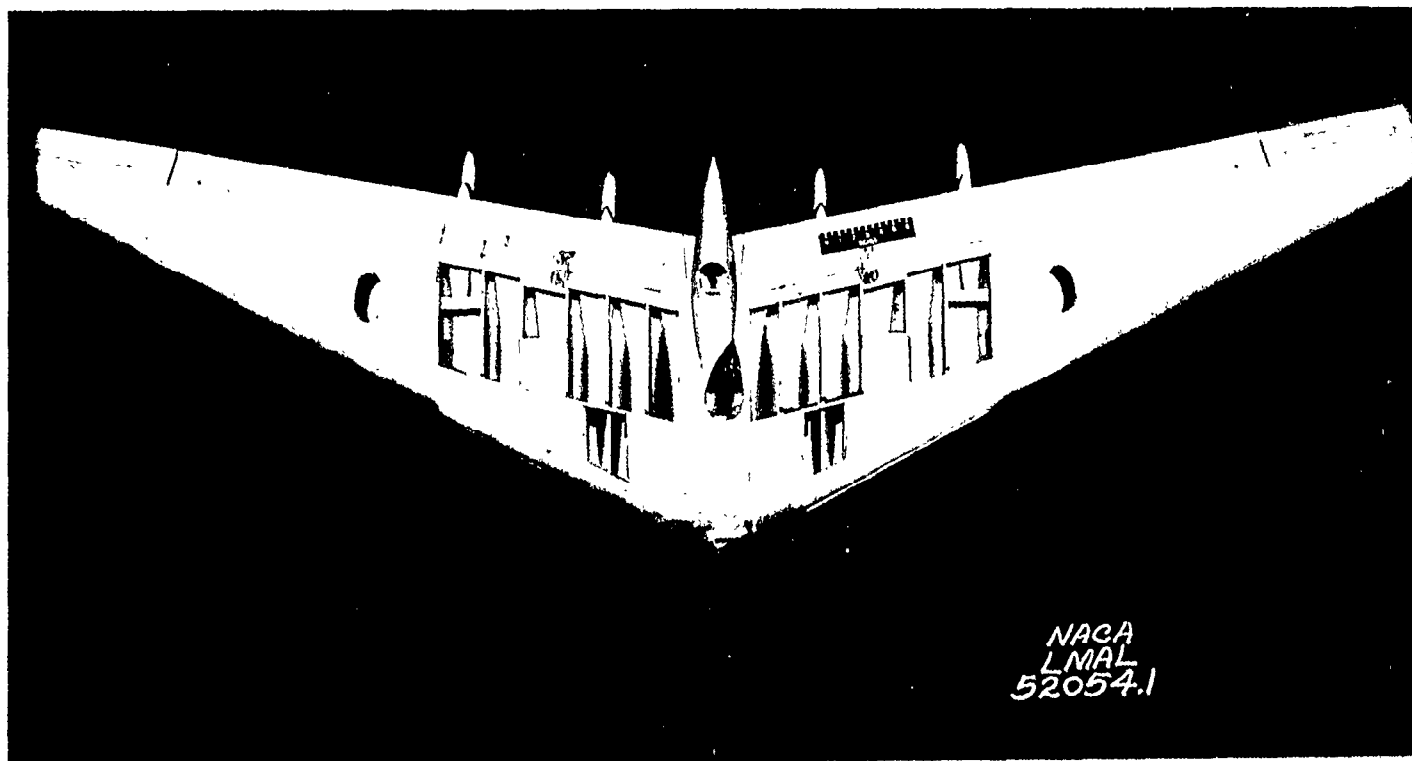
Figure 5.- Bottom view of model with bomb-bay doors, lower turrets, lower ball sighting station, aft part of main-wheel doors, engine doors, and bombardier's window removed.
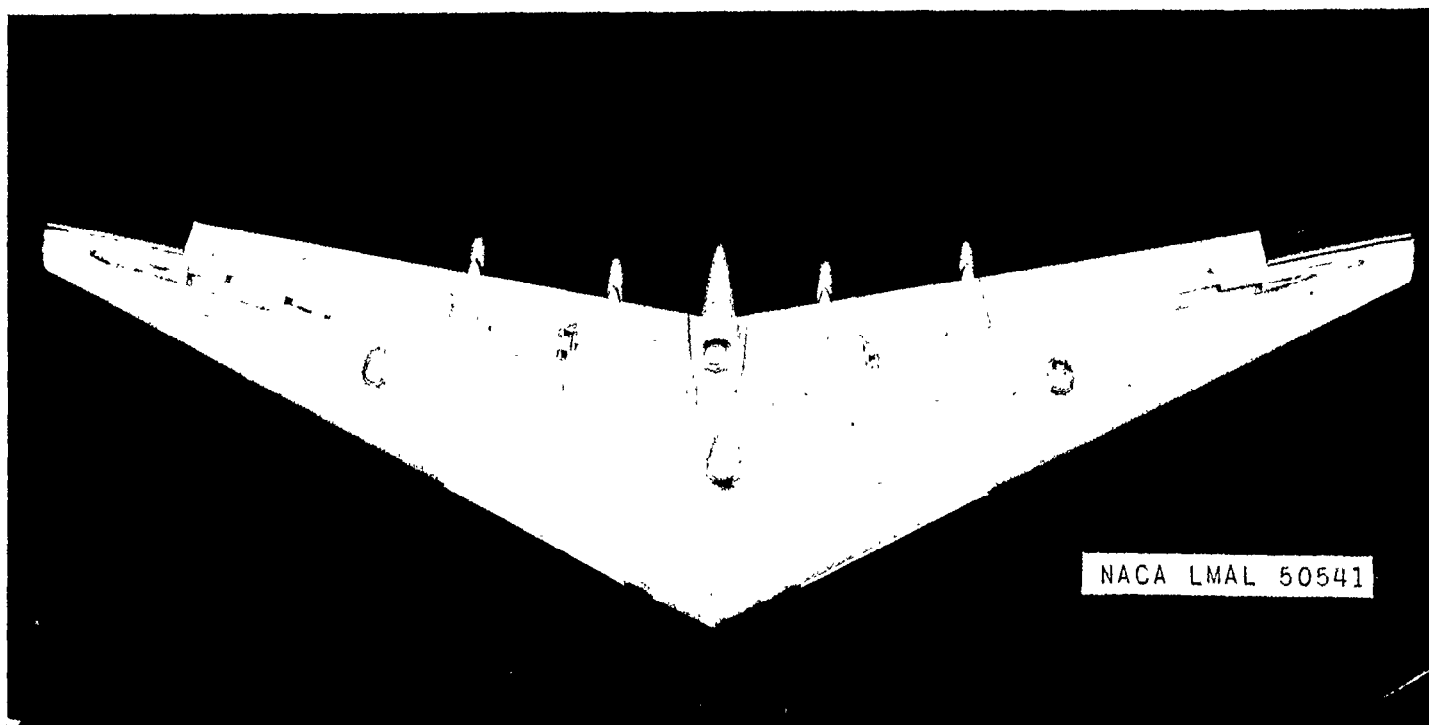
NACA LMAL 50541
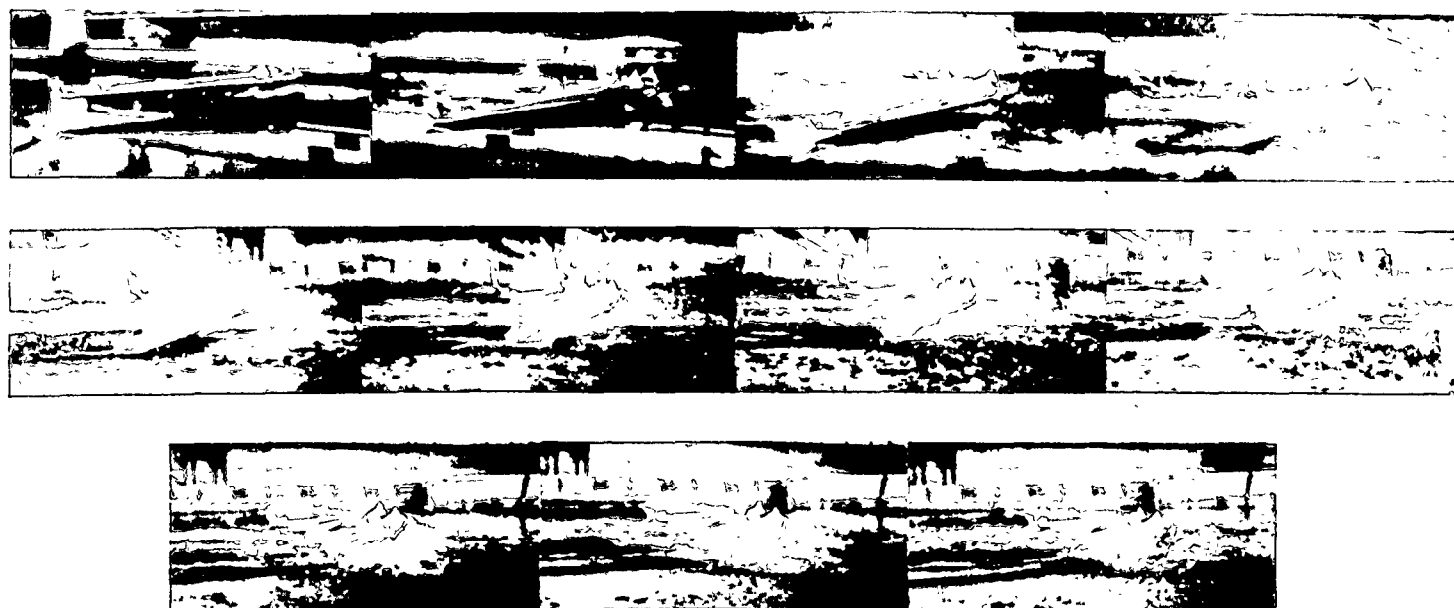
Figure 6.- Bottom view of model with planking torn from wing near tips.

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(a) Landing attitude, 14°; landing speed, 113 mph.

Figure 7.- Sequence photographs at 0.56-second intervals of model ditchings with simulated failure of bomb-bay doors, lower turrets, lower ball sighting station, aft part of main-wheel doors, and bombardier's window. (All values are full scale.)
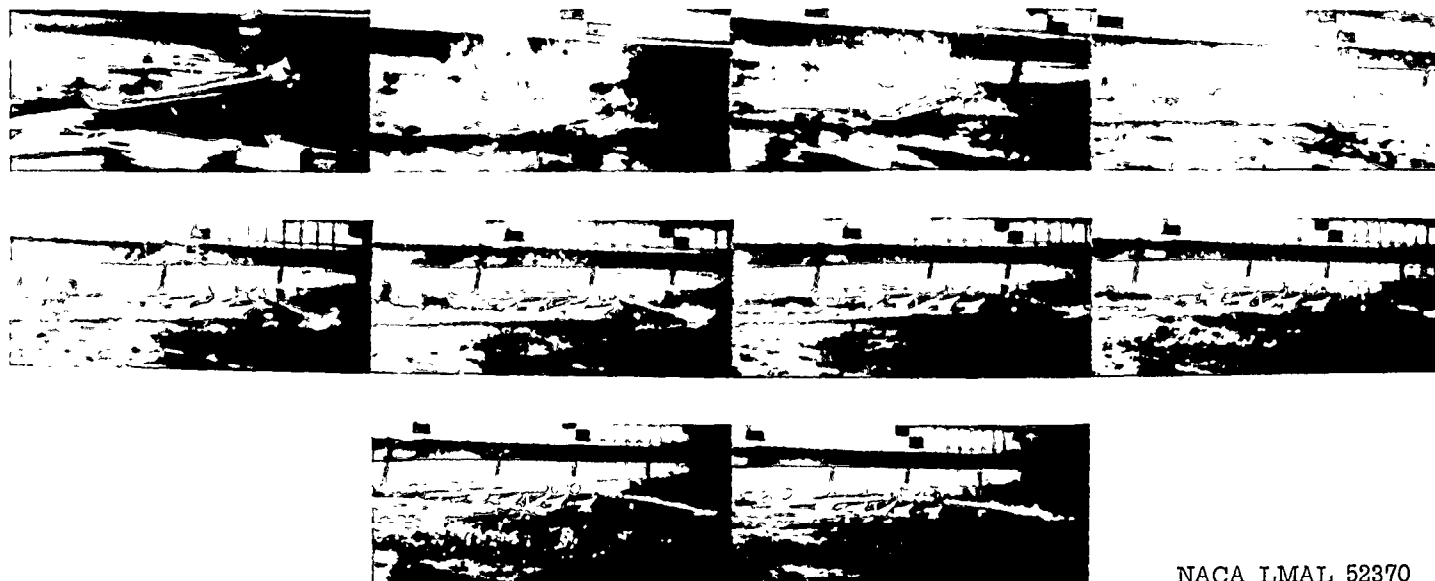
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(b)   Landing attitude, 9°; landing speed, 128 mph.

Figure 7.- Continued.   NACA

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(c)   Landing attitude, 4°; landing speed, 143 mph.

Figure 7.-   Concluded.

Figure 8.- Typical time-histories of longitudinal decelerations for ditching tests of the model with flaps full-down and with simulated failure of the bomb-bay doors, lower turrets, lower ball sighting station, aft part of main-wheel doors, engine doors, and bombardier's window. (All values are full scale.)

(a) Landing attitude, 14°; landing speed, 113 mph.

(b) Landing attitude, 9°; landing speed, 128 mph.

(c) Landing attitude, 4°; landing speed, 143 mph.

(a) Landing attitude, 14°; landing speed, 113 mph.

(b) Landing attitude, 9°; landing speed, 128 mph.

(c) Landing attitude, 4°; landing speed, 143 mph.

Figure 9.- Typical time histories of lateral accelerations for ditching tests of the model with flaps full down and with simulated failure of the bomb-bay doors, lower turrets, lower ball sighting station, aft part of main-wheel doors, engine doors, and bo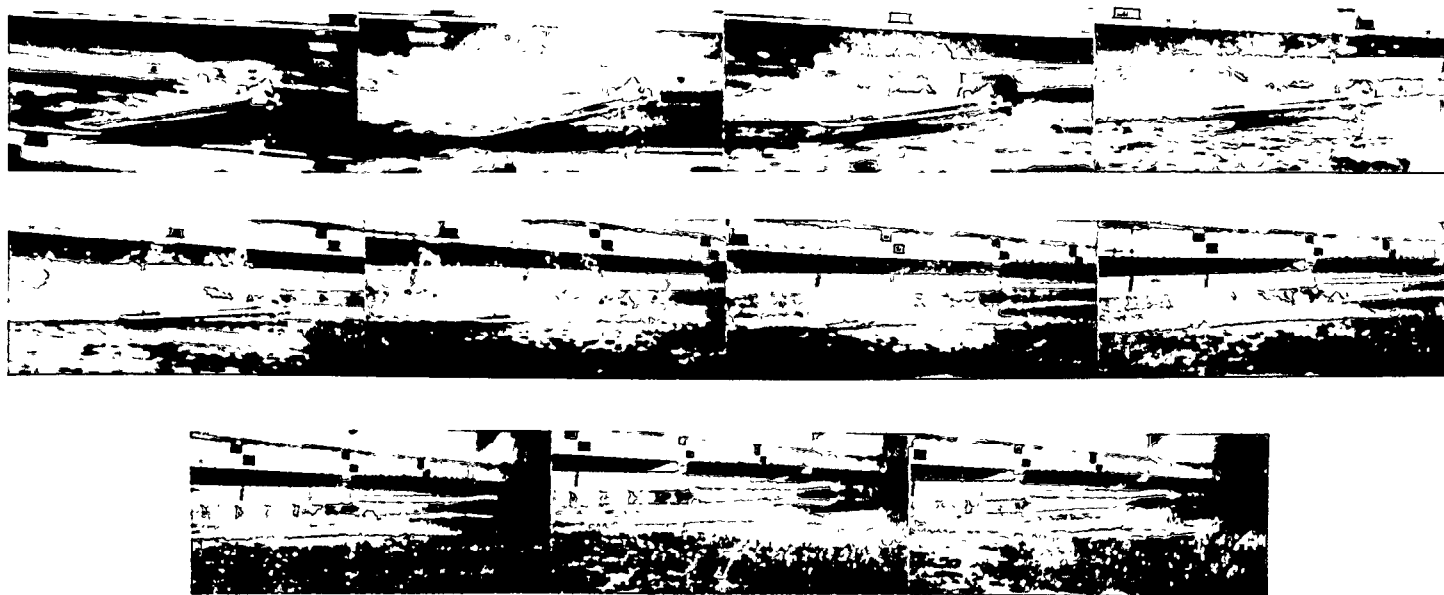mbardier's window. (All values are full scale.)